RELIABILITY OF PUMPING STATION DESIGN[1]

By Clarence Goldsmith

The consideration of the reliability features connected with water works pumping stations is deserving of more earnest study than has been accorded it in times past. Continuous service, as every water works man realizes, is an essential requirement, and in his own plant any condition which causes an interruption of service is generally remedied to prevent a recurrence. It is believed that considerable advantage may be gained in the study of the broad and general problem derived from past experiences in water works systems in general, which have resulted in interruption to service. The items which must be considered in a pumping station designed to give a maximum of reliability include the building, all equipment and suction and discharge connections; if the supply of power is from an outside source the reliability of this source must also be considered.

The pumping station and other buildings of the plant should contain no combustible material in their construction. Combustible wainscoting, roof, sheathing and floors are objectionable, as in some instances they add enough fuel to allow a small fire to injure machinery. The author knows of an instance in Texas where a metal-clad building, with wooden frame, burned and completely wrecked an irrigation pumping station. Wooden lockers and partitions for offices should be entirely eliminated. Non-fireproof buildings should have incombustible roof covering; cornices and gutters should be metal flashed; the several sections, particularly any with high-potential generating or transforming equipment, should be separated by parapeted fire walls and the openings between the several sections should be protected by fire doors or wired glass in metal frame. In most cases, it is not practicable to remodel an existing building so that it will be fireproof at a reasonable cost, but for any but a frame station, the installation of a complete sprinkler equipment, with the removal of as much wood work as possible, will render the building reasonably safe. All stations should have their exposed window

[1] Read at the Richmond Convention, May 8, 1917.

and door openings protected, which can be esthetically and economically done with wired glass in metal frame. Where a plant is in a closely built up section or seriously exposed, it is desirable to add further protection by installing a water curtain and in serious cases metal or tin clad shutters should also be added. This protection against exterior fires applies just as much to the mutually exposing buildings of the plant as to some outside building.

The hazards within should be properly guarded by taking the following precautions: Electric wiring should be installed in conduit, in accordance with the National Electrical Code; the stock of oils and greases, if in any quantity, should be stored in a separate building or a properly constructed oil room, and those for immediate use should be kept in approved safety containers. Clean waste should be carefully stored, preferably in metal-lined covered boxes, and dirty waste kept in approved cans until burned. If coal is stored in large quantities, care should be taken to prevent spontaneous combustion by observing the rules laid down by the latest brochure issued by the Bureau of Mines. Stations using fuel oil or gas from coal gas producers need special consideration. For fuel oil, underground storage is the only safe practice, but if aboveground tanks are used, they should be air tight and at a safe distance.

During the past ten years, records show that fires occur in one to three pumping stations each year and the results are in some cases serious. In 1909, the Atlantic City, N. J., pumping station was destroyed by fire, which started at 2.30 o'clock in the morning and it was 10.00 o'clock in the evening before a pump was started; a new fireproof station has since been erected. In 1910, the Powell station at Fort Worth, Tex., was totally destroyed and about one-half of the supply was put out of service thereby; an emergency supply from the river was utilized and no shortage occurred.

The Walnut Hill pumping station in Omaha, Neb., was destroyed by fire in 1915, but the supply was maintained from the Poppleton avenue station. After this fire, both the Poppleton avenue and Minne Lusa stations were protected by complete sprinkler equipments.

The City of Lynn, Mass. was one of the first to install sprinklers in its pumping station. Now that the added reliability afforded by these installations is becoming more widely appreciated, the number of such installations is increasing and stations are so protected in the above named cities and in Baltimore, Md.; Tauton and Millers Falls, Mass.; Westerly, R. I., and Racine, Wis.

Where a station is so located that there is possibility of floods interfering with its operation, every precaution should be taken to guard against such an occurrence by the maintenance of substantial dykes about the plant, providing stop logs to be inserted in proper grooves in such door and window openings as may be necessary and sufficient sump-pump capacity to free the building of any water which may gain entrance at time of high water.

Stations located in wooden areas should have the growth cleared for a radius of several hundred feet, and even though the building exterior is incombustible it is advisable to provide a water curtain.

The equipment should next be considered. In this discussion, the different types of units is not a matter of consideration as, if of modern and suitable design, and well constructed and installed, their dependability is practically on a par; if there be any superiority, it is in the following order of naming:

a. Reciprocating or centrifugal pumps driven by reciprocating or turbine steam units.

b. Centrifugal or reciprocating pumps driven by electric motors.

c. Pumps operated by water power.

d. Centrifugal or reciprocating pumps operated by internal combustion engines, adapted for the service.

In considering any item in connection with a water works system, it must be recognized that at all times and at all seasons of the year, the plant must be capable of furnishing nearly full demands; it is reasonable to expect serious fires at any hour, and on this basis it might be assumed that the system should, under any possible condition, furnish this demand at the time of the maximum rate of consumption. This does not appear entirely reasonable, as these maximum rates are only of a few hours duration for a few days in the year. In general, it is believed that if the consumption rate is taken at the maximum for any twenty-four hour period, this will approximate the average day time rate sufficiently close to ensure good service under any condition.

In any study of a water works design, the element of time must be considered; it is believed that under ordinary conditions a period of five days is sufficient to make temporary repairs and renewals, or to get partially dismantled equipment back in service. It is recognized that this is not sufficient for major repairs or complete new installations, but these are of such uncertain duration that fully safeguarding against them is not possible.

It also appears reasonable to figure fire flow on the basis of occurring throughout a ten-hour period. Conflagrations usually are of longer duration, but if a fire has passed the ten-hour stage, and is still at maximum height, the question of water supply is of little moment.

If the works have no elevated storage and are dependent upon direct pumpage, the capacity of pumping equipment in service, including that in reserve which is available for operation, should be sufficient, even with the two largest units out of service, to allow the works to deliver at a rate equal to the maximum daily consumption and in addition the quantity necessary to meet the fire flow demands. That two units should be out of service at one time is not a matter of uncommon occurrence and the only reason that such occurrences are not given more prominence is because the possible maximum demands, due to a large fire at the time of even average consumption rates, do not occur while the units are out of service. However, the records of some such instances are at hand and it may not be out of place to mention some of the more important in order to show the possibilities of such occurrences in any station where there are a number of units in service.

At the Toledo station in 1912, one of 15,000,000-gallon pumps was undergoing repairs when the piston rod in another 15,000,000-gallon unit broke, and during the two ensuing days the city was dependent upon three 5,000,000-gallon pumps, the combined capacity of which was little in excess of the quantities required for domestic use. In 1913, a bearing failed in a 10,000,000-gallon pump at Dayton and thirty minutes later a grab claw on the valve gear of a second pump broke and for a period of two hours, required to make repairs, only about one-half of the normal pressure could be maintained. This pump had only been put back in operation for a little over an hour before fire pressure was required. Many other such occurrences of a similar nature could be cited, but these are typical of all.

Where there is elevated storage available, the pumping capacity which must be provided when the two largest units are out of service can be reduced, depending upon the amount of storage. In general, the remaining capacity should be sufficient, in connection with the flow from the storage, to furnish maximum consumption for five days and at the end of that period be able to deliver maximum and fire flow for ten hours.

The fact that a sufficient quantity is in storage to make up the deficiency in pump capacity is not sufficient, but ample main capacity must be provided from the storage to the system to deliver the quantities required to offset the deficiency.

The problem of determining the adequacy under varying storage and pump capacities resolves itself into three general conditions.

1. When the remaining pump capacity (after deducting the capacity of the two largest units) equals or exceeds the maximum daily consumption rate, the pump capacity plus 2.4 times the storage should be equal to the maximum daily consumption plus required fire flow; pumping capacity, consumption and fire flow must be expressed in gallons per twenty-four hours.

2. When the remaining pump capacity is less than maximum daily consumption and the storage is less than five times the maximum daily consumption less the pump capacity, the pump capacity plus one-fifth the storage should be equal to the maximum daily consumption plus the fire flow rate.

3. When the remaining pump capacity is less than the maximum daily consumption and the storage is greater than five times the maximum daily consumption less the pump capacity, the fire flow rate must be equalled by 2.4 times the storage after five times the maximum daily consumption minus the pump capacity has been deducted.

When the supply is dependent upon both low-lift and high-lift pumps, suitable reserve, as outlined above, must be provided for both groups. If in such plants the suction to the high-lift pumps is so arranged that the low-lift pumps can be by-passed, as is frequently the case where the supply is filtered, suitable provision should be made to apply hypochlorite or chlorine gas sterilization to the raw water in case of failure of the low-lift pumps.

In plants with steam generating plants, a sufficient boiler capacity should be provided to allow a reserve of one-fourth of the entire capacity and in any case at least one boiler.

In direct pumping systems, sufficient boiler capacity should be kept under steam at all times to deliver the required fire flow in addition to the domestic rate being delivered at the time; those boilers not required for normal operation should carry at least one-half the required steam pressure. Where the stack capacity is sufficient or forced draft is provided, it is safe to allow 50 per cent overload for return tubular boilers and 100 per cent for water tube

boilers. The stack capacity can be determined from tables found in most engineering hand books, but can be more accurately determined by the chief engineer from actual operating experience.

The steam piping should be so installed, either in a loop or in duplicate lines, that the failure of any pipe or valve will not reduce the available capacity of the plant below that required to maintain the maximum daily consumption rate and fire flow. As repairs to steam lines are more easily made than other repair work, it is believed that the time mentioned above might be reduced from five days to two days, thus allowing a smaller storage requirement to off-set the danger of interruptions to service from this cause. The steam piping in many stations is the outgrowth of additions which have been made as the several units have been added to the equipment, and it is not an uncommon occurrence to find, in a study of the lay-out, one or more valves, the failure of which would necessitate shutting down the major portion or, in a few cases, the entire station. Such a condition is frequently brought about by making a cross-connection between two lines in order to assure flexibility of operation. Non-return valves should be so installed that a blowout in either boilers or steam lines will be automatically controlled. This is a necessary precaution in any plant as a safeguard against loss of life, and in plants serving a direct pumping system is absolutely a necessity in order to assure continuous operation unless the steam piping is sectionalized, which method is not calculated to allow the desired flexibility and economy in operation.

Several of the more common systems of steam piping will be discussed, which are open to objection from the reliability standpoint, both in direct pumping systems and in systems where the storage available is not sufficient to maintain the full required supply for the period required to make repairs or to get cold units into service.

In a plant where there are two boiler houses, one on either side of the pump room, one frequently finds a single header extending through the pump room, receiving its supply from both boiler rooms and divided by gates between the branch steam line to each pump and gates for controlling each boiler and boiler room. Where the boilers in only one of the boiler rooms are kept under steam, a failure in that boiler room will put the plant entirely out of service until steam can be raised on the boilers in the other boiler house, a condition not possible under two to three hours, and a failure of the steam piping in the pump room will put from one to all the pumps out of service.

Some important stations have the steam piping laid out in a loop, with one leg of the loop in the pump room and the other in the boiler room, having valves between the branches of each steam line to the pumps and a single gate subdividing the portion of the loop in the boiler room; the failure or repair of the valve in the boiler room will necessitate shutting down the entire plant.

In the station of a rapidly growing city, the original plant, which consisted of two pumps supplied from four boilers, all connected to a single header, was enlarged by the addition of the same number of units installed in the same manner. In order to secure the desired flexibility of units, the two headers in the boiler room were cross-connected by a connection with a single valve. In a short time this valve failed and its replacement necessitated a complete shutdown of the plant. Feed lines to boilers should be laid out with equal care in order to assure their reliability, and a sufficient number of feed pumps and injectors should be installed to provide an adequate reserve. More than one immediate source of supply should be available.

If gas is used for fuel either under the boilers or in gas engines, it should be available from two independent sources, and if one source is a producer plant there should be storage sufficient to operate at a capacity sufficient to furnish the maximum daily consumption and fire flow during the time required to put the producer into service. A supply of fuel for the producer should be kept on hand. The gas piping should be designed and gated in a manner similar to the steam piping.

Where oil is the fuel, it should be kept in underground storage with at least five days' supply on hand, and should be supplied to the engine or boiler by force feed with duplicate feed pumps and piping and valves so arranged as to safeguard the reliability of operation the same as required with the steam piping.

Where oil and gas are used for boiler fuel, provision for burning coal, if a suitable supply is on hand and the boilers are equipped to use it, will take the place of the duplication necessary with the other fuel.

Where stations are operated by water power, the adequacy of the supply throughout the entire year must be assured or sufficient power provided from other sources to maintain the full required supply at all times.

When pumps are electrically operated the generating station

supplying them should have the same features of reliability that are required in the pumping station, i.e., in regard to building construction and private protection, and reserve equipment.

The electric transmission lines should be underground and in duplicate; each circuit should have sufficient capacity to operate the plant at its required capacity. A commercial circuit with other consumers is not as reliable as a circuit for the exclusive supply of the station. The transmission lines should be so arranged that the renewal of any switch or transformer or the burn-out of any cable will not prevent maintaining the required supply. Contracts or agreements should provide that the service to the pumping station have preference over all other service.

All equipment should be so installed that repairs can readily and conveniently be made; a traveling crane even in stations having only a few small size units will be found an economical investment. In order to facilitate repairs a sufficient stock of small repair parts, such as packing, valves, valve springs and studs, spare valves and fittings should be kept on hand in ample quantities. Experience has shown that spare blank flanges, caps and plugs are most useful to keep in stock.

The fuel supply should be assured by providing sufficient storage capacity to provide for any probable interruption in delivery, and the contract for furnishing fuel should contain a bond proviso to assure delivery.

The suction may be brought to a pump well, either through an open channel or gravity conduit; be delivered to the suction side of the pump under some head, or be drawn to the pump by suction through a considerable length of pipe, as from a well field. The intake from a lake, pond or stream should be of substantial construction at a point where the stream bed will not change or silt up; be protected by grids and screens, arranged for cleaning, to intercept eels, ice and floating débris; if anchor ice is liable to form, provision for utilizing live stream should be made.

Reciprocating pumps are frequently so installed that they are required to operate under a suction lift of 20 to 25 feet, although it is a well recognized fact that it is desirable to so plan the installation as to have the lift as low as possible and, in fact, it is occasionally possible to deliver the supply under some head. Foot valves are frequently installed, particularly when the lift is high, but their value appears questionable, for many pumps are today operating

with high suction lifts without them; others have them but they are so out of repair that they actually introduce an added lift on account of the friction loss introduced. Centrifugal pumps, however, require adequate and reliable means of priming when operated under any suction lift whatever. In this case the foot valve is not only subject to the previously named objection, but has in several instances failed by rupture due to the full discharge head against which the pump works being imposed on the suction piping. Vacuum pumps are the most reliable means of maintaining suction and are ordinarily employed. They should be in duplicate and the piping so installed that the failure of any pipe, fitting or valve will not put more than one-half of the capacity or, at most, two of the units, out of service. The air pump suction should be in the form of an inverted U column over 32 feet high, so as to preclude the possibility of water getting over into the air pump. It if is not possible to run the column up the desired height, and automatic control of the pump is provided to maintain the water level at a predetermined height, the suction pipe at this level should have its area considerably enlarged to prevent the erratic operation of the pump due to the necessarily rapid changes of the water level in a suction column of small area.

Except when each pump has an independent suction, the individual suctions should be gated and the suction piping should be so gated that the failure of any pipe, fitting or valve will not put more than one-half the capacity or at most two units, out of service.

The design and installation of the discharge piping is of particular importance and the failure to consider carefully the problem in all its phases is almost certain to lead to serious failures. In many cases the discharge piping, like the steam piping, is the outgrowth of successive increments made in pumping units, and little thought has been given to the ultimate results of these piecemeal additions. The layout should be so designed and developed that the failure of a single pipe will not put more than one unit out of service and the failure of a valve will not put more than two units out of service. Such a provision will ensure a capacity equal to the combined maximum daily consumption and fire flow if adequate reserve pump capacity is provided. Although this provision does not seem unreasonable, yet a study of the discharge connections about a large number of stations show that in many cases a large portion, and in some cases the entire capacity, of the station will be put out of serv-

ice by the failure of a single valve, and frequently the failure of a pipe or fitting will cause almost as serious results.

One of the most common weaknesses is that of having the entire supply dependent upon the integrity of one valve. For a typical example, assume a station with four pumps, with two pumps discharging into one force main and the remaining two pumps into another force main, and that these force mains are cross-connected outside the station with a single valve in the connection. During the past winter the failure of a valve in such a cross-connection did occur and, owing to futher complications, it was nearly 24 hours before the service was restored. The bonnet of the valve blew off under a pressure no greater than was normally carried. To repair this valve both lines had to be shut off, putting the entire station out of service. The employees at the pumping station, in closing the valves which controlled the mains outside the station, twisted the stems off two of the valves, so that when the valve which originally failed had been temporarily repaired it was impossible to put either force main in service until their respective valves had been overhauled. The failure of these two valves when they were operated, emphasizes the importance of inspecting and operating such important control valves at frequent intervals (say monthly) and keeping them in condition.

When we come to the consideration of the discharge system of some of our larger stations, where pipes as large as 48-inch are required, the question of valves and their operation becomes one of paramount importance. Not only as a point of economy but in order to increase the reliability and ease of operation, it is desirable to use valves of a size smaller than the diameter of the pipe, set in the line with reducers and increasers on either side. The additional friction loss produced by the use of a 36-inch valve in a 48-inch line, a 30-inch valve in a 36-inch line, and a 24-inch valve in a 30-inch line will be negligible and in some cases even smaller valves might be considered, for a service test of a 20-inch valve in a 36-inch line showed an excess loss of only 0.4 foot head when the line was carrying 14,000,000 gallons.

Provision should be made for the prompt and rapid operation of these valves, not only to enable the service to be restored quickly in case of a failure, but to prevent the undermining of other pipes, which would be liable to cause additional failures of the pipe system. Complete and accurate plans of all such connections are very essential for intelligent operation.

In 1909, and at least once prior to that date, the failure of a high service discharge pipe at the Massachusetts Avenue Station at Buffalo resulted in the complete failure of the supply to this service for a number of hours. The discharge piping consisted of one 30-inch, seven 36-inch and three 48-inch pipes which were so cross-connected and gated outside the station that any pipe could serve either the high or low service. All gates were manually operated; some were in a gate house and others were in brick vaults within a radius of 150 feet about the gate house. Considerable time was required to operate these gates and as it could not be determined which pipe had failed, about twice as many had to be operated as were actually required to shut out the section which had failed.

At the Lardners Point pumping station in Philadelphia on May 28, 1914, at 6 a.m., a 48 by 48 by 42-inch cast-iron tee, forming a portion of the discharge of pump No. 11, a 20,000,000-gallon unit, failed. At the time of the break four pumps of the same capacity were discharging against a head of 110 pounds into the 60-inch main leading to Oak Lane reservoir. No check valves were installed on the pumps or mains. The automatic cut-offs on all the pumps worked satisfactorily, but before the valves on the discharge pipe could be closed the basement, which was about 20 feet below the surrounding ground, was flooded. The steam lines, feed water lines to boilers, sump-pumps and control valves were submerged and normal operation was not resumed until 8 a.m., May 29.

Such accidents as these show the importance of providing pump discharges with check valves, preferably at several points along the line if the distance is great, and so equipping the gate valves that they can be quickly operated. This is ordinarily done by providing motor or hydraulically operated valves, and their control should be from a central point. Such installations are to be found in some of the high pressure fire service pumping stations. Valves which automatically close when an excess flow or decrease in pressure occurs from the failure of the line are also now being built and are used on the penstocks of some hydro-electric plants. Such valves can be utilized with advantage in discharge lines, as they can be so adjusted as to close without producing an appreciable ram on the line.

Some type of meter, with a continuous recording device, for measuring the discharge from the station, should be provided and pumps should be overhauled when their slip shows an increase. Care should be taken not to take a second pump down for overhauling, unless it

is absolutely inoperative, while another unit is out of service. Efficient operation generally makes for reliability, therefore the keeping of records of station operation should be considered essential. The plans of buildings, equipment and piping should be filed convenient for ready reference at the station.

It has been the tendency in many water works systems to install large units; considering only the question of economy of operation this is sometimes of a decided advantage, and it is often possible to install a large unit at a material saving in price per million gallons over that of two small units. Also it is recognized that it is good policy for a water works superintendent to get as much capacity as possible when he has his committee or board committed to the purchase of a pump. However, there is a decided element of unreliability connected with this; with the larger units, the effect of a shut-down is much more serious, as often half the station capacity will be affected. These large units are harder to repair and in some cases more apt to have defective material.

Particularly in direct pumping systems, much greater reliability can be obtained if the pumps are of such capacity that under ordinary conditions two will be in service, one operating at capacity and the others idling, to pick up any excess demand; if this is not done, the second pump should be kept warm.

The installation of sufficient high-duty reciprocating units to provide the requisite reserve would in many instances require a large expenditure not only for the additional unit but also for its housing, but fortunately the centrifugal pump is available for such service and in fact has many distinct advantages over the reciprocating unit, although it cannot on the whole be classed as superior. The space occupied per million gallons of capacity is very much less than for other types and an additional unit can, in many cases, be installed in space not now occupied; the work required for ordinary maintenance is very much less than for other pumps, which is becoming a more important consideration as the cost of labor increases; the discharge mains and distribution system are not subjected to the pulsations which are present in a more or less marked degree in the discharge from reciprocating units; when pumping into a direct pressure system, the pressure can be more uniformally maintained and the system will not be subjected to so great a variation in pressure by sudden changes in consumption rates; the slip of the pump will not increase so rapidly, and if clear water is being pumped the

renewal of the rings should be infrequent and require much less time than is needed to overhaul the several valve decks of a plunger pump; when driven by a modern steam turbine the duty developed very nearly approaches that which moderately well maintained units of other types can develop over extended periods of service; where two services at different pressures are supplied from one station the possibility of running the centrifugal pumps in series by two-staging, or in some cases by three-staging, should be taken advantage of even though the maximum efficiency can not be obtained when pumping against one of the pressures; under similar conditions one centrifugal unit can frequently be so installed that it can serve either one of two services by having one suction connection to the suction supply and another to the lower of the two services being supplied.

DISCUSSION

Carleton E. Davis: It is well to aim high and have an ideal standard as a permanent object lesson. In this paper ideal conditions have been presented. Such conditions naturally call for unlimited financial resources. Unfortunately many of us do not have control of the purse strings, and it is frequently a question of using limited funds to the best advantage possible. The human element enters largely into the case in that an absolutely fool-proof pumping station has not yet been devised. Mental lapses will occur from time to time and cannot be entirely overcome or eradicated.

In speaking of certain units, the author uses the terms large and small in an absolute way. These terms are relative and it must be recognized that a large unit in one instance may be small in another. Again, the author apparently indicates the necessity of keeping a certain number of units in reserve. Here again the standard should be relative and not absolute. A station with two pumps may have 50 per cent reserve and only one pump out of service, whereas another station with twelve pumps and only one pump out of service may have 8.5 per cent reserve.

J. N. Chester: Has the author seen or inspected a water works that complied with all the requirements he has laid down, and does he know of any community or private corporation that will furnish the money to build a station and equip it with pumping machinery, steam lines, boilers, suction and discharge pipes, etc., in accordance

with the advice given? Naturally every man looks at things from that particular angle the advocacy of which will be of the most benefit to the interest he represents. It is the view of one interest that the author has presented, but, on the other hand, has he thought about the complications that would be introduced into the water works system by his ideals, which would tend to multiply the possibility of accidents and of interference with the service? For instance, take the advocacy of four valves at every street crossing made some years ago by the underwriters' inspector at Charleroi, Pa. The speaker's reply to that proposal was that it would introduce complications rendering the service far less reliable than the one-way piping which had been adopted, that had at about every third street a cross-connection and valves, not always four, but sufficient valves to guard against all reasonable possibilities.

Whether or not we can have sufficient pumping units and duplicates, in reserve, so we can have the two largest units down and still meet the maximum domestic plus the maximum fire demands is doubtful. The speaker has never seen such a water works. The author has inspected over one hundred plants. The speaker has installed machinery in more than half that number, but never complied with such specifications, never having served either a municipal or private plant that would furnish the money to gratify such a desire, if he possessed it.

The recommendation that arrangements be made so that if the low service breaks down the supply may be drawn from the raw water source, and that chlorination apparatus should be provided for use then, is bad and those who have been impressed by it should turn back in the *Proceedings* to a paper written by Doctor Mason on the emergency intake, wherein he cited numerous cases of typhoid fever epidemics arising from such a practice. It is unnecessary to repeat here the experiences he there cited as attributable to the emergency intake. Its equivalent is the by-pass around a filter plant to enable raw water to be introduced into the mains. At Butler, Pa., 1700 typhoid fever cases developed through reverting to the raw water that had been used two years earlier, before the use of filtered water. Better had blocks of buildings been burned down in that town than lose the 113 people they did through by-passing the filter plant.

The speaker is in hearty sympathy with the best kind of fire protection and with the total elimination of combustible material in pump-

ing stations; also in favor of plenty of machinery, and of elevated storage where it can be obtained, with steam pipes sufficiently in duplicate and enough pumps so that the plant will be ready to serve when anything breaks down; but he does not believe that these things can be carried to the extent recommended in this paper.

F. W. Cappelen: The speaker agrees with Mr. Chester that perhaps there should not be any emergency connections. In one place in Minneapolis there are two 50-inch lines about 10 feet apart running parallel for about four miles. One of these lines is a force main, and the other a distribution main. These two lines were cross-connected in several places, so that either could be used for either purpose, pumping or distribution. These lines were constructed to the reservoir system before the purification plant was installed. Since the installation of the purification plant, these two lines, of course, are used for each distinct purpose, and the cross-connections have no further purpose.

At the speaker's request, the State Board of Health made a thorough examination of the filtration works and the entire system in connection therewith. The Board found everything in first class condition, and only suggested that these cross-connections be cut off, being afraid that a leak between the raw water force main and the pure water distribution main might occur.

Clarence Goldsmith: In regard to Mr. Chester's statements about emergency connection, there is nothing in the paper in favor of them. They exist in many plants; and in half a dozen plants visited, the superintendents have provided for sterilization of the emergency supply in case they need to use it. If these connections exist it is desirable to have sterilization provided for. In two cases where low-lift pumps failed and the water was treated, there was no epidemic.